For Paul S- & Robert V-

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INTERPRETATION OF REFRACTIVE CONDITIONS IN THE PERIPHERAL FIELD OF VISION

A FURTHER STUDY

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In a former paper[1] an apparatus and method were described for refracting the eye for the peripheral field of vision, and curves were given showing the refractive situation for eighteen cases. It is our purpose in the present paper to make a more comprehensive analysis than was given in that paper of the type of information about the eye that may be obtained by studying the refractive situation from the center to the periphery of the field. Some of this information, so far as we know, can be obtained in no other way of studying the eye that has as yet been described.

The two most important factors in the ametropia for the peripheral field are (1) the effect of the oblique incidence of the rays of light from objects in the peripheral field on the clearness of the image formed, and (2) the effect of size and shape of the eyeball and of anomalies and irregularities in the conformation of the retina on the distance of the percipient elements from the nodal point of the refracting system. With reference to the first of these two factors, it will be remembered that clear images are formed by lenses only when the object to be imaged is located on the principal axis of the lens. When the object is displaced from the principal axis, a distortion of the image occurs which varies in amount with the angle of displacement of the object or with the angle of incidence of the light on the lens. In general, the effect of varying the angle of incidence is that of adding a weak plus sphere and a strong plus cylinder with its axis at right angles to the plane of incidence. The major effect is thus to create a strong astigmatism. A simple formula for this effect in the two meridians may be expressed as follows:[2]

$$F_1 = \frac{F(\mu - 1)}{\mu \cos b - \cos a}$$

$$F_2 = F_1 \cos^2 a$$

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1. Ferree, C. E.; Rand, G., and Hardy, C.: Refraction for the Peripheral Field of Vision, Arch. Ophth. **5**:717 (May) 1931.

2. Laurence, L.: General and Practical Optics, London, The Orthos Press, 1908, p. 163; ed. 3, 1920, p. 245.

In these formulas, F represents the focal length of the lens in question; F_1, the focal length in the plane of least refractive power; F_2, the focal length in the plane of greatest refractive power; a, the angle of incidence of the light; b, the angle of refraction at the first surface, and μ, the refractive index of the lens. In both planes, then, the image is brought nearer to the lens in the plane of the oblique incidence and very much nearer in the plane at right angles to it. The refractive effect for the eye would thus be a comparatively small amount of myopia compounded with a strong myopic astigmatism, the amount of both defects varying with the angle of incidence. The effect on vision is modified, however, by the fact that the distance of the retina from the nodal point of the refracting system decreases rapidly as the distance from the fovea is increased. In the greater number of emmetropic eyes the effect of this is to bring the retina between the foci in the two planes or to cause a mixed astigmatism which increases in diopter value as the periphery of the retina is approached.

As a result of the possible combinations of the factors, length of eyeball, shape of eyeball and strength of refracting system, however, many situations may occur. The possible variations in the shape of the eyeball depend on the relation of the length of the polar to the equatorial axis. If these axes are approximately equal in length, the shape of the eyeball is approximately spherical; if the polar axis is longer than the equatorial, the shape tends toward an ellipsoid; and if the equatorial is longer than the polar, the variation in shape is toward an oblate spheroid. If the variation is toward an ellipsoid, a tendency toward hyperopia is exerted in the peripheral field; if toward an oblate spheroid, a tendency toward myopia. The influence of a strong refracting system is toward myopia; also, it tends to increase the difference between the length of focus in the two planes as the periphery is approached, and therefore to increase the astigmatism due to the angle of incidence of the light. The influence of a long eyeball is in general toward myopia and a short eyeball toward hyperopia. Any number of combinations of these factors and of variations in the relative importance of their influence may occur.

The following examples may serve to illustrate some of the possibilities and their effect on the refractive situation in the peripheral field:

1. In an emmetropic eye with a strong refractive system and an eyeball approximately spherical and long enough to render the eye emmetropic for central vision, the focus in one plane would be in front of the retina and in the other behind it, and a strong mixed astigmatism would be found.

2. In an emmetropic eye with a weak refracting system and a correspondingly long eyeball, oval or ellipsoidal, the focus in both planes might fall behind the retina for all or a greater part of the peripheral field and a compound hyperopic astigmatism occur.

3. In an emmetropic eye with a strong refracting system and a proportionately short eyeball of the shape of an oblate spheroid, both foci might fall between the retina and the lens for the more remote parts of the field and a compound myopic astigmatism be found.

4. In hyperopic ametropia with a weak refracting system and an ellipsoidal eyeball, the amount of hyperopia may increase in both planes as the periphery of the field is approached; and in myopic ametropia with a comparatively weak refracting system and an elongated ellipsoidal eyeball, the amount of myopia may decrease in both planes as the periphery of the field is approached. This characteristic influence of the ellipsoidal shape in combination with a weak refracting system toward hyperopia in the peripheral field is doubtless the determinative factor in the eyes classed as type B in our former paper.

5. In hyperopic ametropia with a short eyeball shaped to resemble an oblate spheroid, the defect may change to myopia at some point in the peripheral field. This shape of eyeball rarely if ever occurs in connection with myopia. If it does, the effect is to increase the myopia toward the periphery of the field.

In the foregoing characterizations as to shape, it should be remembered what slight deviations toward an ellipsoid or an oblate spheroid are required to produce several diopters of effect in connection with a refracting system as strong as that which is present in the eye. Such results as we have obtained do not require at all marked variations in the shape of the eyeball for their explanation in terms of the principles which have been noted. From the data we have obtained in a study of the refraction for the peripheral field, certain cases have been selected to illustrate well marked situations that occur. The results for these cases have been plotted in the form of curves. These curves are shown in charts 1 to 4. In the charts, the results for the horizontal plane, the plane of incidence of the light, are plotted as a solid line; for the vertical plane, the plane at right angles to the plane of incidence of the light, as a broken line. Degrees of eccentricity are plotted along the horizontal coordinate and diopters of refractive defect along the vertical coordinate. The condition of no refractive defect is represented by a horizontal line drawn through the center of the chart. Diopters of hyperopia are plotted above this line along the vertical coordinate; diopters of myopia, below it. The diopters of hyperopia and myopia are expressed in terms of corrections needed, plus and minus, respectively. The value of the interval of Sturm can be read along the vertical coordinate at corresponding points between the solid and the broken lines.

For the interpretation of the curves, the following points may be noted:

1. The relation of both curves to the base line of the chart indicates the type of astigmatism that is present in the peripheral field. If both are above the base line, the astigmatism is compound hyperopic; if both are below, the astigmatism is compound myopic; if one is above and the other is below, a mixed astigmatism is present. The interval between the two curves represents at the various points the diopter value of the astigmatism, the interval of Sturm.

2. The curve drawn as a broken line gives information as to the shape of the eyeball. That is, this curve represents the refraction in the vertical plane at the various points examined, and the refraction in this plane is not strongly affected by the angle at which the examination is made. The distance of the retina at the various points from the nodal system of the refracting system is, therefore, dominantly determinative of the shape of this curve.

3. The breadth of the interval of Sturm, particularly the rate of its increase together with a comparison of the shape of the curves for the horizontal and vertical planes, gives important information as to the strength of the refracting system. This is due to the great effect of the strength of the refracting system on the rate of shortening of the focus for the obliquely incident rays in the horizontal as compared with the vertical plane.

4. A comparison of the breadth of the interval of Sturm in the temporal and nasal halves of the field gives information as to whether there is an asymmetry in the refractive situation for these two halves of the field; and a comparison of the shape of the curves for the horizontal and vertical planes, information as to whether the asymmetry, when present, is caused dominantly by the refracting system, e.g., a tilting of the lens, or by some peculiarity in the conformation of the retina or in the shape of the eyeball.

5. A consideration of the strength of the refracting system in relation to the refractive condition at the center of the field gives information as to the length of the eyeball.

RESULTS

Chart 1 shows approximate emmetropia in four cases—two with mixed astigmatism of different amounts in the peripheral field, one with a compound hyperopic astigmatism and one with a compound myopic astigmatism.

Chart 1 *A* shows a high mixed astigmatism in the peripheral field. An inspection of the curve representing the refraction in the vertical plane indicates an approximately spherical eyeball. The interval of Sturm is broad, but not unusually so, and symmetrical in the two halves of the field; therefore, the refracting system presumably is of medium strength with no asymmetry. Since the eye is emmetropic at the center of the field and the refracting system is of medium strength, the eyeball may be assumed to be of medium length. In this case, therefore, the indications are: a refracting system of medium strength, symmetrically placed with reference to the axis of the eye, an eyeball of

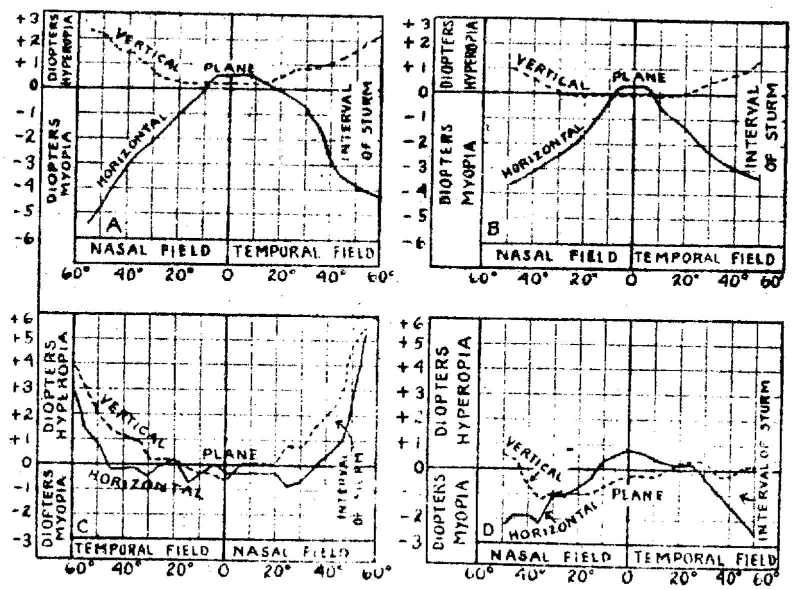


Chart 1.—Four cases of emmetropia, two with mixed astigmatism of different amounts in the peripheral field, one with a compound hyperopic astigmatism and one with a compound myopic astigmatism: *A*, right eye, without cycloplegia, type A; *B*, right eye, with cycloplegia, type A; *C*, left eye, without cycloplegia, type B; *D*, right eye, without cycloplegia, type A.

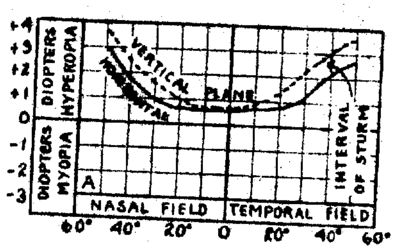
medium length, approximately spherical in shape, and a symmetrical conformation of the retina.

Chart 1 *B* shows a low mixed astigmatism in the peripheral field. Again, it may be inferred from the curve for the vertical plane that the eyeball is approximately spherical. The interval of Sturm is, however, not so broad as in chart 1 *A*. The indications are, therefore, a weaker refracting system and, since the eye is approximately emmetropic for central vision, a correspondingly longer eyeball. The refraction seems to be practically symmetrical for both halves of the field; therefore nothing unusual is to be suspected with reference to the placement of the lens and action of the refracting system or in the conformation of the retina and shape of the eyeball.

Chart 1 *C* shows compound hyperopic astigmatism in the peripheral field. The shape of the curve for the vertical plane and the high diopter value of the hyperopia in the far periphery of the field indicate in this case a tendency toward an ellipsoidal eyeball. The interval of Sturm is narrow and decreases in breadth as the periphery of the field is approached. A prominent feature of this case also is the fact that the curve for the horizontal plane is concaved upward in the peripheral field, the pitch of the curve being quite steep in the more remote peripheral portions of the field. This is doubtless a combined effect of weak refracting system and of an ellipsoidal eyeball. A weak refracting system in connection with approximately emmetropic vision at the center of the field indicates an eyeball which is more than usually long. The refractive situation in both halves of the field seems to be practically symmetrical. In terms of the principles stated earlier in the paper, the picture here, then, is that of an emmetropic eye with an elongated, ellipsoidal eyeball, a weak refracting system and practically no refractive asymmetry in the two halves of the field.

Chart 1 *D* represents an eye approximately emmetropic for the center of the field and with a compound myopic astigmatism in the greater part of the peripheral field. The curve for the vertical plane is broad and flat and but little concaved upward. The indication of this is an eyeball flattened at the back, with a shape tending toward that of an oblate spheroid. The curve for the horizontal plane is also comparatively broad and flat and concaved downward, giving in relation to the curve in the vertical plane a representation of compound myopic astigmatism with the rule in the near peripheral field and against the rule in the far peripheral field. The interval of Sturm is rather narrow, indicating a comparatively weak refracting system. It is also fairly symmetrical in the two halves of the field, indicating little if any refractive asymmetry. Since the eye is approximately emmetropic for the center of the field and the refracting system somewhat weak, a rather long eyeball may be inferred. This chart seems to represent an emmetropic eye with a weak refracting system and a correspondingly long eyeball of a shape tending toward that of an oblate spheroid, and with comparatively little refractive asymmetry.

Chart 2 represents two cases of ametropia in which the curves for both the vertical and horizontal planes are concaved upward; that is, the change toward the periphery of the field in both planes is in the direction of hyperopia. In the first of these, chart 2 *A*, the eye has a low degree of hyperopia in the center of the field which increases quite sharply in both planes toward the periphery, but more sharply in the vertical than in the horizontal plane, thus causing a compound hyperopic astigmatism. The shape of the curve in the vertical plane indicates a somewhat ellipsoidal eyeball. The curve for the horizontal plane follows closely on a broader scale the curve for the vertical plane. The interval of Sturm is narrow, indicating that the refracting system is weak. It is also symmetrical in the two halves of the field. Since the eye is hyperopic at the center of the field and the refracting system is weak, the inference is that the eyeball is short. The important refractive features of this eye, then, may be summarized as follows: simple hyperopia in the central field changing to compound hyperopia toward the periphery of the field; a weak refracting system; a short, ellipsoidal eyeball, and no refractive asymmetry in the two halves of the field.



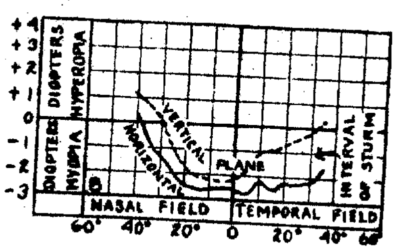


Chart 2.—Two cases of ametropia in which the change in the periphery of the field is in the direction of hyperopia: *A*, right eye, with cycloplegia, type B; *B*, right eye, without cycloplegia, type B.

In the eye represented in chart 2 *B*, a fairly high but unequal degree of myopia is present in both planes at the center of the field. Toward the periphery of the field the myopia decreases sharply in both planes, but the amount of the astigmatism increases. The curve for the vertical plane indicates that the eyeball is quite strongly ellipsoidal. The interval of Sturm is narrow, from which it may be inferred that the refracting system is weak, at least not unduly strong, and that elongation of the eyeball is the determinative factor in the eye's myopic condition. A comparison of the breadth of the interval of Sturm in the two halves of the field shows some refractive asymmetry, and a comparison of the shape of the curves for the horizontal and vertical planes indicates that this asymmetry may be due both to the refracting system and to the conformation of the retina or shape of the eyeball. The refractive features of the eye are, then, compound myopic astigmatism at the center of the field with a change toward a lower value of myopia and higher value of astigmatism toward the periphery of the field, a weak refracting system, an elongated ellipsoidal eyeball and a comparatively small amount of refractive asymmetry in the two halves of the field.

Chart 3 represents a selection of three cases from a group of cases of ametropia. In *A* is represented an eye which has 2 diopters of myopia at the center of the field and a slight astigmatism. Toward the periphery of the field this changes into a high value of compound myopic astigmatism and finally into a still higher value of mixed astigmatism. The curve for the vertical plane indicates that the eye is strongly ellipsoidal. Toward the far periphery of the field the interval of Sturm is broad, but the shape of the curve for the vertical plane indicates that the shape of the eyeball plays a more important part in this than has been the case in the emmetropic and weakly ametropic eyes which we have thus far been considering. This is, of course, in conformity with the views that are usually held of the more strongly

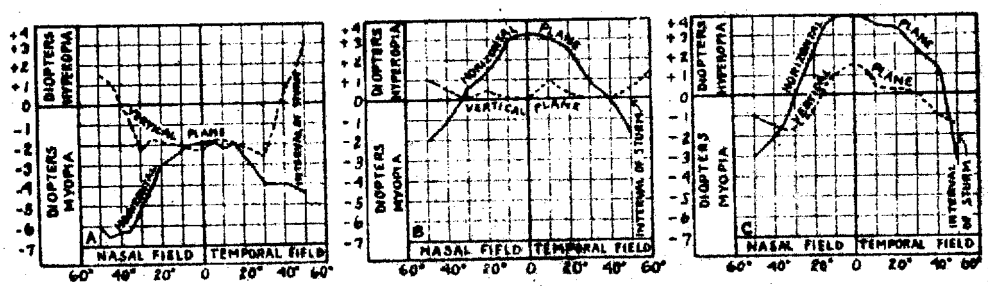


Chart 3.—A miscellaneous selection of three cases of ametropia: *A*, right eye, without cycloplegia, type A; *B*, right eye, with cycloplegia, type A; *C*, right eye, with cycloplegia, type A.

myopic eyes. The refracting system is probably not unduly strong in this case. An elongated eyeball is therefore indicated. Both the breadth of the interval of Sturm and the shape of the curves for the horizontal and vertical planes indicate that some refractive asymmetry is present in the two halves of the field. The chart thus represents an eye which has a simple myopia at the center of the field, a compound myopic astigmatism in the paracentral field and a mixed astigmatism in the far peripheral field; the eyeball is unduly long and ellipsoidal; the refracting system is medium or strong, and there is some refractive asymmetry in the two halves of the field.

Chart 3 *B* represents an eye which is strongly hyperopic in the horizontal plane and emmetropic in the vertical plane at the center of the field, and hyperopic in the vertical plane and myopic in the horizontal plane in the far peripheral field. An analysis and interpretation of the data for such an eye are, of course, difficult to make. That is, so far as the refractive situation is concerned, an astigmatism represents two types of eye compounded into one. However, the data may contribute something helpful to the better understanding of the eye in question. The shape of the curve for the vertical plane is broad and flat, indicating an eye of the oblate spheroid type. The interval of Sturm is broad, and the curve for the horizontal plane is sharply concaved downward. Since the horizontal is the weaker refracting plane of this eye and there is a strong effect of increase of angle of incidence in this plane, it does not seem probable that the refracting system can be weak. There is little refractive asymmetry in the two halves of the field. The indications are, then, a short eyeball of the oblate spheroid type, a comparatively strong refracting system having less refracting power in the horizontal than in the vertical plane and practically no refractive asymmetry.

Chart 3 *C* represents an eye hyperopic at the center of the field but much more hyperopic in the horizontal than in the vertical plane. Toward the periphery of the field the hyperopia decreases rapidly in both planes but more rapidly in the horizontal than in the vertical plane, changing in turn into a compound myopic astigmatism with the rule and a compound myopic astigmatism against the rule. The curve for the vertical plane is concaved downward instead of upward, as has been the case for all the other eyes which we have as yet had under consideration, and crosses the base or emmetropic line at an eccentricity of about 15 degrees in the nasal field and 30 degrees in the temporal field. That is, from these points on toward the periphery of the field the focus in this plane falls between the retina and the nodal point of the refracting system instead of beyond it. Since the length of the focus is not strongly affected by the angle of incidence in this plane, the change from hyperopia to myopia at these points in the field would seem to indicate for this eye a decided deviation in shape toward an oblate spheroid. The curve for the horizontal plane is sharply concaved downward, and the interval of Sturm is fairly broad. Since the horizontal is the plane of weaker refracting power, this again, as in chart 3 *B*, would seem to indicate that the refracting system cannot be weak. As in chart 3 *B* there is here also little refractive asymmetry in the two halves of the field. The characteristics for this eye seem in general to be very similar to those for the eye represented in chart 3 *B*, namely, a short eyeball, oblate spheroid in type, a fairly strong refracting system and little refractive asymmetry. The deviation in shape toward an oblate spheroid, however, is probably considerably greater than in case of the eye represented in chart 3 *B*.[3]

3. It is interesting to note that 3 *B* and *C* represent the eyes of brothers, 11 and 13 years of age, respectively.

Chart 4 represents cases selected from a group showing a pronounced refractive asymmetry in the two halves of the field. These cases are comparatively infrequent, but they may be found in course of time in any clinic. As was pointed out in the former paper, it is chiefly for the better understanding of, and more intelligent treatment in, these cases that there is a practical need for studying the refractive situation in the peripheral field. In chart 4 *C* the asymmetry may sustain a causal relation to the ocular deviation which was found to be present. In the other two cases the character of the asymmetry is not such as to lead us to suspect any considerable effect on the muscle balance of the two eyes.

Chart 4 *A* represents the superimposition of an asymmetry on an eye which seems otherwise to be of the type shown in charts 1 *A* and *B*.

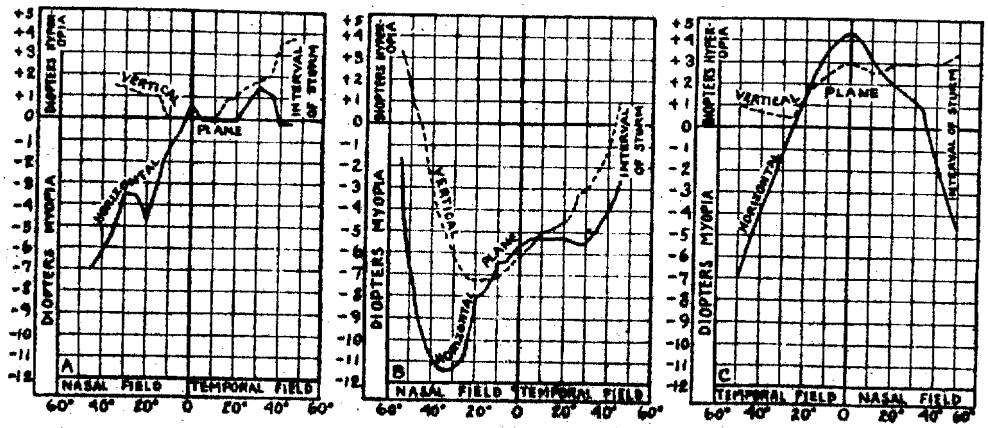


Chart 4.—Three cases having a pronounced refractive asymmetry in the two halves of the peripheral field: *A*, right eye, without cycloplegia, type C; *B*, right eye, without cycloplegia, type C; *C*, left eye, type C, extreme presbyopia, no accommodation.

The curve for the vertical plane is concaved upward and has a breadth and shape that would indicate that the eye is probably of the spherical type. The interval of Sturm is of medium breadth, which would indicate a refracting system of medium strength. Since the eye is emmetropic for the central field, it may be inferred that the eyeball is correspondingly of medium length. A comparison of the breadth of the interval of Sturm for the two halves of the field together with the shape of the curves for the horizontal and vertical planes for these halves of the field indicates that the asymmetry is in all probability due primarily to the refracting system, e. g., to a tilt of the lens toward the temple. This would increase the angle of incidence for the nasal field and decrease it for the temporal field, and cause comparatively a corresponding amount of shortening of the focus in the nasal field and lengthening of it in the temporal field. Under test, this case showed practically no muscle imbalance. An inspection of the chart shows no reason for suspecting a muscle imbalance, so far as the refractive situation centrally and peripherally is concerned. That is, the eye is nearly emmetropic at the center of the field, and no deviation in either direction could be expected to improve the refractive condition.

In chart 4 *B* is shown a case of high myopia complicated with a pronounced refractive asymmetry in the two halves of the field. The curve for the vertical plane is narrow and strongly concaved upward. Also, the apex of the curve is displaced 20 degrees to the nasal side of the center. The curve would seem to indicate an elongated narrow eyeball, the posterior half of which is strongly ellipsoidal and asymmetrical. The curve for the horizontal plane is also concaved upward with its apex displaced about 35 degrees to the nasal side of the center of the field. At this point the value of the myopia is 11.5 diopters. From here the myopia decreases sharply and becomes 1.5 diopters at 65 degrees. At the center of the field the myopia has a value of 5.5 diopters, and at 45 degrees to the temporal side of the center, 3.5 diopters. The interval of Sturm is comparatively narrow, but broader on the nasal than on the temporal side. The shape of both curves and both the breadth and the shape of the zone representing the interval of Sturm indicate that the shape of the eyeball is the dominant factor in both the myopia and the refractive asymmetry. The test both with the Maddox rod and with prisms showed 10 prism diopters of exophoria. When fixation was taken with the right eye alone, a deviation of 20 degrees toward the temple was shown. Measurements of the cornea showed no asymmetry, and the value of the curvature in both meridians fell within the normal range. Such asymmetry of action as there may have been in the refracting system was probably due, therefore, to the lens, e. g., to a tilt or inclination of the lens toward the temple. The color fields for red and blue, 1 degree stimuli, showed a contraction in the upper half. The field for 1 degree green was very small. The ocular deviation in this case was probably due to the high degree of myopia. Refractive asymmetry apparently had little or nothing to do with it. This may be inferred from the fact that when the myopia at the center of the field was corrected, the deviation practically disappeared and by the fact that a deviation of the eye either temporalward or nasalward could not have been expected to render any effective service in clearing up the defective imagery.

In chart 4 *C* is shown a refractive asymmetry superimposed on an eye of the type represented in chart 3 *B*. At the center of the field there was a high compound hyperopic astigmatism, 3 diopters in the vertical and 4.5 in the horizontal plane. In the nasal field in the vertical plane there was little change in the hyperopia as far from the center as 50 degrees. In the temporal field it had decreased to 0.5 diopter at 25 degrees and was 1 diopter at 50 degrees. In the nasal field in the horizontal plane it decreased to zero at 35 degrees, and at 50 degrees there was 4.5 diopters of myopia. In the temporal field the hyperopia decreased to zero at 25 degrees, and at 50 degrees there was 7 diopters of myopia. It is significant to note that the nearest approach to emmetropia came at 25 degrees from the center in the nasal field. The defect here was 0.5 diopter of simple hyperopic astigmatism.

The shape of the curve for the vertical plane is broad and flat and tilted downward in the temporal field and slightly upward in the nasal field. It is slightly concaved downward around the center of the field, but not in the more remote periphery. These facts would indicate a shape of eyeball tending toward that of an oblate spheroid, also probably some asymmetry of shape. The curve for the horizontal plane is sharply concaved downward. Also, the interval of Sturm is broad. Since the refracting power in the horizontal plane is 1.5 diopters weaker than in the vertical plane, it can be inferred from the sharpness of the concavity of the horizontal curve downward together with the breadth of the interval of Sturm that the refracting system is comparatively strong; at least it is not weak. Shortness of eyeball is probably, therefore, a strong if not the dominant factor in the hyperopia at the center of the field. The total picture presented by the curves for the horizontal and vertical planes and the zone representing the interval of Sturm indicates that the refractive asymmetry may be due to either shape of eyeball or refracting system or both.

The vision in this eye, the left eye, was 20/200, and could not be improved substantially by correction. The patient stated that prior to fifteen years ago there was, so far as he knew, no vision. An examination for central scotoma gave negative results. That is, while the test object was seen vaguely at the center, it was seen equally clearly there and in the field surrounding the center for 15 to 20 degrees in all directions. A test with the Haitz charts showed that when both eyes were open the vision in this eye was entirely suppressed. When the right eye was closed, however, the figure for the left eye was seen. When both eyes were open there was no observable deviation in either eye; but when the right eye was closed the left immediately turned inward and took a fixation approximately 25 degrees from the median plane. It will be remembered from the chart that the nearest approach to emmetropia in the left eye was at an eccentricity of 25 degrees in the temporal field. When using this eye alone, the patient apparently turned the eye inward about 25 degrees in order that objects in front should be in the line of least refractive error and the clearest image be formed on the retina.

In the course of the examination of the eye the blind spot was mapped on the tangent screen of the Ferree-Rand perimeter with a 0.5 degree white stimulus on a black background. With the eye turned toward the center of the arc of the perimeter, the fixation object could not be seen with sufficient clearness to give satisfactory control of fixation. In order to secure a correct fixation, the left eye was lined up by means of the telescope inserted in the hollow axle of the perimeter. A large fixation cross (3 cm. in diameter) was moved along the horizontal meridian temporalward to the point at which it could be seen most clearly. The highest visibility was attained at a point approximately 25 degrees from the center of the arc. This, it will be remembered, was the point in the field at which there was the smallest error of refraction, 0.5 diopter simple hyperopic astigmatism. With the fixation object at this point, a fairly satisfactory control of fixation was secured and a map of the blind spot was made.

CONCLUSION

Attention may be called to the following points as incentives for a wider study of the refractive situation in the peripheral field:

1. The possibility of determining both the type and the amount of refractive error at every point in the nasal and temporal halves of the horizontal meridian as far out as 60 degrees by a method that is reasonably feasible, satisfactory and accurate.

2. The important relation which the refractive conditions in the peripheral field sustain to acuity in the peripheral field, to achromatic and chromatic sensitivity in peripheral vision and the limits of the form and color field, and to the anomalies and irregularities in peripheral space perception. In this connection it may be noted that the conditions for the formation of an image are so bad for objects in the peripheral field that one can only marvel that peripheral vision is as good as it is, and that the peripheral portions of the retina should have attained as high a development as they have.

3. The ability to detect and determine the amount of refractive asymmetry in the two halves of the field of vision, and the possibility of determining within rather wide limits in cases of refractive asymmetry whether the defect is in the refracting system and its placement in relation to the axis of vision, or in the conformation of the retina or shape of eyeball, or in both.

4. The possible bearing of asymmetrical refraction in the peripheral field on the explanation of cases in which central vision cannot be substantially improved by correction in eyes which show no central scotoma.

5. The rôle which asymmetrical refraction may play in cases of ocular deviation and the bearing that the demonstration of such a condition may have on treatment.

6. And, finally, the possibility of determining roughly the conformation of the retina and the shape of the posterior half of the eyeball by refracting the eye for the peripheral field; of obtaining information as to the comparative length of eyeball and strength of refracting system in both emmetropic and ametropic eyes, and of estimating with a fair degree of certainty the relative importance of length of eyeball and strength of refracting system as causal factors in the refractive defect in hyperopic and myopic eyes.